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Utilization of Aspen Pellets as a Partial Roughage Replacement for Lactating Dairy Cows

Deborah Sharples Kipp

UTILIZATION OF ASPEN PELLETS AS A PARTIAL ROUGHAGE REPLACEMENT FOR LACTATING DAIRY COWS

BY

DEBORAH SHARPLES KIPP

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PARTIAL ROUGHAGE REPLACEMENT FOR

LACTATING DAIRY COWS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Dr. David J. Schingoethe   Date

Dr. John G. Parsons   Date
Head, Dairy Science Department

ABSTRACT

A complete switchback design using ten lactating cows divided into two groups of five was used to evaluate rations containing either (A) 30% dry matter from aspen pellets, 30% DM from corn silage, and 40% DM from a 28% crude protein concentrate mix, or (B) 60% DM from corn silage and 40% DM from the concentrate mix, to determine if aspen could serve as a partial roughage for lactating dairy cows. All cows were at least 80 days into lactation at the start of the trial. Aspen contained on a DM basis, 1.9% crude protein, 80.3% neutral detergent fiber, 64.5% acid detergent fiber, and 16.88% lignin. There were no significant ration effects on milk production, composition, or flavor; except for slightly higher amounts of 18:0 and 18:1 fatty acids of milk fat from cows fed aspen. Adjusted means for rations A and B were as follows: milk production, kg/day (20.94, 21.35), % milk fat (3.49, 3.50), % milk solids (12.26, 12.22), % milk protein (3.09, 3.08), and milk flavor judged by an experienced panel using the ADSA-DFISA score card with 10 as best score (8.77, 8.77). Cows fed ration A consumed 19.36 kg DM and those fed ration B consumed 19.28 kg DM on a daily basis. Rumen samples were taken via the stomach tube 3-4 hours after feeding the fourth week of each period. Rumen ammonia was similar for both groups. Concentration of total volatile fatty acids for cows fed rations A and B (48.71, 63.17 moles/ml) was lower for the aspen fed cows. The results of this study indicated that aspen can serve as a partial roughage replacement for lactating dairy cows.

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This work is the proud example of my parents who believe that achievement begins with broadening the mind.

I dedicate this work to my husband Bill for his understanding and encouragement that made this work easier to accomplish.

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INTRODUCTION

The aspen tree (Populus tremuloides Michx), has many characteristics that make it potentially useful as a feed for ruminants. First of all, it is the most widespread tree species in North America. It occupies sizable areas which would include the Great Lakes region, the Rocky Mountain region, and the Black Hills of South Dakota. Secondly, aspen is a very fast growing and short lived tree. Only a small fraction of the aspen population reaches a size large enough for lumber. Also, aspen is less lignified as compared to other trees and it contains up to 75% carbohydrates which can serve as a source of energy for the ruminant animal. It is, however, deficient in other nutrients, such as protein, vitamin A and phosphorus.

Ruminant animals can digest and utilize complex carbohydrates such as cellulose. Roughages containing cellulose are a required part of a ruminant ration, not only to provide energy, but to induce tactile stimulation of the rumen walls and to promote cud-chewing which in turn increases salivation and supply of a buffer for maintenance of rumen pH and normal rumen fermentation. In lactating dairy cow rations, this roughage affect in the rumen indirectly serves to maintain fat levels in milk by favoring the production of acetate in the rumen.

When traditional roughages are in short supply or high in price, it would be an advantage to have an alternate fibrous feed source that could meet the roughage requirements of the ruminant. One such source, the aspen tree is readily available. It has potential as a ruminant feed.

The objective of this research is to measure the response of lactating dairy cows when replacing 50% of the roughage with aspen pellets. In such a ration, aspen pellets would supply 30% of the total ration dry matter. Cow responses measured include milk production and composition as well as feed intake.

LITERATURE REVIEW

I. General interest in feeding wood and wood residues to ruminants.

Initial interest in feeding wood materials to ruminants began in the early 1900s due to a shortage of available carbohydrates during World War I. Beckman (12, 13) found that the nitrogen, fat, starch, ash and food value of wood was lower than that for straw. Also, in the early 20th century, Haberlandt (45) discussed the possibility of using the starch, oil and, in some cases protein and glucose, found as reserve substances in the storage tissues of sapwood as a food for people and domestic animals.

Recently the potential of using wood materials as a feed for ruminants has been stimulated not only by a demand for compact roughage substitutes in the event of feed shortages, but also by an abundance of wood wastes generated from the logging and pulp industry (11). The U.S. Forest Service has calculated that there are over 100 million tons of unutilized wood wastes produced each year by the lumber industry (36). These wastes contain up to 75% carbohydrates that can offer potential energy in ruminant rations (6, 8, 69). Accumulating wood and bark wastes present a problem when they cannot be converted into something of value since most disposal methods cause pollution (26, 86).

Most untreated woods are quite indigestible. Millett et al. (72), using an in vitro rumen technique, found that of 24 species and subspecies of tree material examined, only aspen, ash, and maple were digested to any extent. Much interest in the partial replacement of traditional forages by wood material in ruminant rations has focused on the aspen tree.

Aspen is the most widely distributed forest type tree, occupying 26% of the commercial forest land in the lake state region alone (18). The aspen forest also extends across Canada and occupies sizable areas in the northeast states and the Rocky Mountains of Colorado and Utah. The Black Hills of South Dakota alone may have over 23,490 hectares of mature aspen stands in need of harvesting and management (58).

Aspen barely attains pulpwood size at maturity. Major use for aspen is pulp or chipboard, but because it is relatively short fibered, the pulp value is lower than that for other trees (18). Large numbers of aspen trees are harvested annually for use in the manufacture of paper and paper products in Canada, Minnesota, Wisconsin and Michigan (34). The aspen logs are often peeled mechanically during the pulping operation and the bark is bulldozed into a pile and burned or left as waste (34). A significant amount of this aspen bark was reportedly being fed to ruminants in parts of drought stricken northern Minnesota in 1977 (85).

Aspen is important in deer and grouse management. Young aspen and its associated species provide browse and forage for deer and it provides a protective cover for grouse (58, 67). Aspen rejuvenates rapidly after fire and therefore helps stabalize the water regime of streams and lakes (18).

Periodic harvesting is necessary to assure an aspen stand (58, 59, 67). Aspen stands begin to deteriorate rapidly after the trees pass maturity. As the aspen trees die they are replaced by more tolerant tree and brush species (18). The weak aspen suckers cannot compete with this vegetation and most of them die. South Dakota Game Fish and Parks was especially interested in managing aspen stands to increase ruffed grouse populations in the Black Hills in order to provide the type of environment sought by this species of bird and other wild animals (59).

Because aspen is not used by the lumber industry in this area, the South Dakota Game Fish and Parks was faced with the problem of dealing with this aspen waste. Feeding it to ruminants is one alternate use.

II. Nutritional value of wood as a feedstuff in ruminant rations.

A. Wood classification, composition and characteristics.

The nutritive value of wood as a feedstuff in ruminant rations is dependent on several important factors. Lignified cellulose such as that in wood offers resistance to the attack of bacteria (25, 46, 94, 96). The extent of digestion of cellulose is related to the availability of the cellulose. Bolker (16) observed that there is a covalent acetal bond that exists between the carbonyl groups of lignin and the hydroxyl groups of some portion of the cellulose. This bond between lignin and cellulose was revealed when he examined wood and pulp by high resolution differential infrared spectroscopy.

Two classified groups of trees which differ in the amount and type of lignin are the hardwoods and the softwoods. Hardwoods are one of the botanical groups of trees that have broad leaves (e.g. aspen, cottonwood, oak, elmwood, etc.). Softwoods are those groups of trees that in most cases have needles or scale-like leaves (e.g. pine, spruce, fir, hemlock, etc.) (38). Softwoods are usually less digestible than hardwoods (91). This is mainly due to the higher lignin content, (25 to 30% compared to 18 to 21% in hardwoods) and the type of lignin present in softwoods (6). The basic building units for hardwood lignin appear to be phenolic nuclei of both propyl guaiacyl and propyl syringyl, whereas for softwood lignin it appears to be almost all propyl guaiacyl type (6).

B. Nutritional value of untreated wood material.

The concept of utilizing woody materials as a feedstuff for domestic animals is very old. Beckman (12) in 1915 determined that the food value of wood was lower than that of straw. Wood contained less nitrogen, fat and ash than straw.

There are several examples of untreated wood being used as a maintenance feed for gestating cows. Slyter et al. (89) evaluated pine sawdust as a roughage replacement in gestating beef heifers. Twelve Angus-Hereford cross bred heifers were separated into two groups of six. One group was fed 9 kg of grass and alfalfa loose hay per day. The other group was fed 9 kg of 25% ground corn, 25% pine sawdust and 50% ground alfalfa. There were no significant differences noted in calving difficulty and calf birth weights, nor were there any abortive tendencies for heifers fed pine sawdust.

Bartlett et al. (9) evaluated the performance of gestating beef cows fed elm sawdust. Three groups of six beef cows in the third trimester of pregnancy were fed either 11.4 kg hay; 22.7 kg corn silage and .45 kg soybean meal (SBM); or 13.6 kg corn silage, 6.8 kg elm sawdust and .45 kg SBM. The sawdust group lost an average of .19 kg per day, but there were no difficulties with calving. Feed cost was reduced 26% when elm sawdust replaced part of the corn silage.

Sawdust has also been used to limit feed intake. Cody et al. (22) evaluated the health and performance of cattle fed pine fiber. There were no toxicity effects when 10 to 15% sawdust was fed along with a concentrate and hay. They also found that grain intake was controlled by including 25 to 45% pine wood fiber with the grain in the diets of 15 dairy calves. Dinius et al. (29) also regulated food intake by feeding oak sawdust to sheep.

Dinius et al. (30) evaluated the intake and digestibility by sheep of rations containing 10% of various roughage substitutes. Of these various substitutes aspen sawdust, oak sawdust and oak flooring waste were fed. The dry matter (DM) digestibilities were 79.7% for the basal diet (no roughage), 77% when 10% aspen replaced part of the basal diet, 75% for oak, 74% for hardwood shavings, and 74% for flooring waste.

Gilbert et al. (42) fed either 15% ground hay or 15% sawdust to growing lambs. Results indicated a significant difference in average daily gain and feed efficiency in favor of the 15% hay ration. When Welton and Baumgardt (97) fed 30 and 50% sawdust to sheep, they found that 6.7% of the decreased food intake was due to palatability.

Anthony and Cunningham (3) carried out a study to compare two levels of hardwood sawdust as roughage sources in all-concentrate rations. The experimental rations were, basal plus 2.5% sawdust and basal plus 10% sawdust. The 2.5% sawdust ration supported the highest gains and the mixture containing 10% wood supported gains equal to the gain of cattle fed basal alone.

Much interest in feeding wood and wood residues to ruminants has focused on the aspen tree as a potential feedstuff. Millett et al. (72) examined the value of untreated wood using an in vitro study. Aspen exibited the highest in vitro dry matter digestibility (IVDMD) of 32%. Soft maple and black ash exibited IVDMD of 20% and 17%, respectively, and the remaining 21 species of trees ranged from 0 to 8% digestible.

Kamstra et al. (57) and Singh (88) evaluated the utilization of aspen trees as a ruminant feed component by comparing rations containing 15 and 48% aspen. Ten Hereford steers per group were fed one of the following rations: (A) all concentrate; (B) 93% alfalfa; (C) high concentrate with 15% alfalfa; (D) high concentrate with 15% aspen; (E) 48% aspen, 13% alfalfa and 32% SBM; and (F) 48% aspen, 13% alfalfa, 16% SBM and 16% chicken manure. Feed efficiency was higher when fed ration E than when fed ration B. Dressing percent was lower when fed rations E and F. Feedlot performance was poor with steers fed ration F, but there were no significant differences in meat characteristics. Steaks from animals fed ration E had lower cooking losses and were more tender than those fed alfalfa.

Singh (88) also evaluated the utilization of whole aspen tree material as a ruminant feed component by feeding 12, 24, 36, and 48% aspen to steers. Each ration was supplemented with SBM and compared to an alfalfa control ration. Steers fed 24, 36, and 48% aspen had higher weight gains and feed efficiencies than those fed the alfalfa control ration. There were no differences in carcass grade and meat characteristics.

Aspen bark is composed of 2.2% protein; 23.1% acid detergent fiber; 13.9% permaganate lignin; and 73% cell wall components (34). Satter (85) fed 20, 35, 50, and 57% aspen bark, replacing alfalfa meal, to a group of four goats. The digestibility of the bark was between 25 and 30%. The dry matter (DM) digestibility of total rations decreased as the amount of bark increased. The addition of long hay to the 53.5% bark ration had no effect on the DM digestibility.

Goodrich et al. (44) discussed the use of aspen bark silage as an alternate feed for beef cows. They recommended that when aspen bark silage is fed to ruminants the ration should be supplemented with crude protein, phosphorus, potassium and vitamin A. They also recommended that aspen bark be finely ground so that it will pass through the digestive trace more rapidly and will not result in reduced feed intakes. They recommended that aspen be ground finely and ensiled at 50% moisture to eliminate the high cost of drying and to reduce the chance of mold formation and spoilage of dry bark.

Goodrich et al. (44) compared cost of rations with and without aspen silage replacement. Hay ration cost estimated is -$109.67/180 days/beef cow; aspen bark silage ration -$105.30/180 days/beef cow; aspen bark silage with -2.3 kg hay $95.34/180 days/beef cow; and aspen bark silage with 4.5 kg hay -$88.84/180 days/beef cow.

Enzmann et al. (34) evaluated the nutritive value of aspen bark silage. Digestibility of dry matter was 36.7% when fed to whether lambs.

Robertson et al. (80) examined the feeding value of aspen silage in rations for yearling steers. When the silage replaced 20, 40, 60% of total dry matter ration, digestibilities were 66.3, 58.9, 50.5%, respectively.

When aspen silage replaced 20, 40, and 60% of total ration dry matter in rations for yearling steers, DM digestibilities were 66.3, 58.9, 50.5%, respectively. When Kamstra et al. (60) and Singh (88) fed aspen silage (whole tree) to pregnant stock cows during winter months, they gained .68 kg daily during the first 45 days of feeding. Cows lost 7.4, 8.8, and 11% of their initial weight when fed mixed hay, 60:40 aspen:alfalfa pellets, and aspen silage over a longer period of time (88). Normal healthy calves were born with no significant differences in weaning weights (58).

Seymour and Kamstra (87) again evaluated aspen silage as wintering feed for bred stock cows. Bred Hereford stock cows were fed either alfalfa brome hay or whole aspen tree silage. All cows remained in excellent condition and gave birth to vigorous healthy calves.

Cattle require some roughage in the ration to maintain normal rumen function. Roughage is beneficial in alleviating such problems as bloat, rumen parakeratosis, and liver abscesses in feedlot cattle. Rumen parakeratosis and liver abscesses are known to occur in ruminants fed high energy rations. High energy diets cause a rapid accumulation of volatile fatty acids (VFA) with accompanying decreases in ruminal pH. These changes may establish a rumen environment antagonistic to the integrity of the rumen wall epithelium (46). Physical qualities present in hay such as coarseness, bulkiness and abrasiveness are necessary to maintain rumen integrity and equilibrium. By the addition of low levels of roughages to high concentrate rations, the incidence of rumen parakeratosis and liver abcesses decreases (48).

Slyter and Kamstra (56, 90) substituted pine sawdust in beef finishing rations. An all concentrate ration was replaced with either 15% ground alfalfa; 15% raw pine sawdust; or 5% and 10% sawdust. There were no significant differences in total gain, final shrunk weights; feed required per unit of gain, and carcass grade and meat quality. The added roughage significantly decreased the occurance of liver abscesses. However, when fine and coarse oak sawdust replaced 5 and 15% of the concentrate, cattle fed fine ground sawdust had a higher indicence of liver abscesses (32, 33). There were no differences in carcass data, blood components and average daily gains.

C. Nutritional value of treated woods:

Cellulose is a valuable energy source for ruminants. The cellulose present in plant material is only partially available to rumen microorganisms. Crampton and Maynard (25) found that the digestibility of the cellulose varied inversely with the lignin content of the feed.

Because carbohydrates of wood are not fully utilized by ruminants, many investigators have studied the effects of treating the lignocellulosic materials to increase the digestibility of such materials.

1. Physical treatments

(a) Fine grinding

In 1915, when Haberlandt (55) discussed the food value of wood, he stated that the woody character of the cell walls containing the nutritive substance is indigestible and only by grinding into a fine meal which breaks and disintegrates the cell walls so that cattle can use the wood as a feeding stuff. It is presently theorized that what makes the nutritive substance, now known as cellulose, indigestible is lignin acting as a physical barrier making cellulose unavailable to the cellulolytic rumen bacteria. Dehority and Johnson (27) state that the decreased digestibility of forages as they mature increases this physical barrier formed by the deposition of lignin around the cellulose fiber. If this is so, physical rupture should make cellulose more available. They showed that ballmilling up to 72 hours increased the in vitro digestibilities of brome grass and orchard grass, especially in more mature samples.

Pew and Weyna (76), and Pew (75) evaluated effects of fine grinding on the lignin-cellulose bond in wood. They reported that fine grinding rendered the carbohydrates completely accessible to the cellulolytic enzymes of Trichoderma viride. When particles of aspen and spruce were of 40 mesh size, the cellulases showed little activity, but when spruce was fine ground by 8 hours of ballmilling and aspen by 5 hours, the cellulases could digest 70% of the spruce and 80% of the aspen. Virtanen et al. (95) found that birch sawdust cellulose digestibility increased from 13 to 68% and the lignin content decreased from 20 to 14% as particle size was decreased. Digestibility of aspen increased from 15 to 64%; and increased from 5 to 46% for pine. Lignin in pine decreased from 25.6% to 16.1%.

Millett et al. (72) reported that vibratory ballmilling was effective with aspen, sweatgum and red oak in yielding carbohydrate digestibilities approaching those of feed grains (70-80%). Gharib et al. (40) fed poplar bark to 18 growing lambs. The bark was ground through .32, .95, 1.59 cm screens. When rations containing 60% ground bark were fed to the lambs, the DM digestibility was not enhanced.

Grinding poplar, alder and douglas fir through .25 to 2.21 mm screens increased the in vitro rumen digestibility of poplar with little effect on alder and douglas fir (52).

(b) Irradiation

Several studies (52, 66, 72, 79) have indicated that irradiation alters the structure of wood in such a way that makes carbohydrates more available to the rumen microorganisms. When Lawton et al. (66) irradiated basswood with high velocity electrons, in vitro digestibilities increased with increasing irradiation up to 2×10^8 Roentgens. Rumen VFA production in steers reached a peak at 2×10^8 Roentgens, then began to decline with increasing dosage. They suggested that the drop in VFA production and continued weight loss at higher dosages was a result of the carbohydrates being converted to compounds not utilized by the rumen microorganisms.

Millett et al. (72) indicated that irradiation with high energy electrons increased the in vitro digestibility of spruce from 0 to 14% and aspen from 32 to 75%. However, they indicated that the process was very costly and not practical. Pritchard et al. (79) obtained similar data when subjecting wheat straw to gamma radiation. In vitro digestibility of the straw exposed to up to 1 X 10^7 rads slightly increased, whereas exposure to 1 X 10^8 rads or more caused marked increases in digestion. Production of VFA increased only up to 2.5 X 10^8 rads indicating that more than 2.5 X 10^8 rads altered the carbohydrates to a form unsuitable for rumen microorganisms.

Huffman (52) found that alder and fir were more digestible at 2 X 10^8 rads of gamma irradiation and that poplar was more digestible at 1 X 10^8 rads. He also found that irradiation decreased the cellulose, acid detergent fiber and acid detergent lignin of all woods irradiated with no effect on ash. Mater (68) stated that making carbohydrates in wood more digestible to ruminants might be possible as a solution to the increasing problem of waste radioisotopes.

(c) <u>Steam cooking</u>

Steam treatment can also modify the wood to increase the digestibility of hay (15). Heaney and Bender (50) steamed aspen chips at 7.03 to 8.08 kg/cm^2, 160 to 170^0 C for 1-½ to 2 hours. The steamed aspen was fed to sheep at 60% of the total ration along with 40% alfalfa hay. There were no differences in daily gain although feed intake per kilogram of gain was slightly higher for sheep fed wood. When 30% steamed aspen was fed to steers for 120 days, the adjusted rate of gain, intake, and beef meat quality and yield were similar to responses obtained with corn silage (51).

2. Chemical treatment

(a) Alkali

One of the most widely used alkali treatments has been one developed by Beckman (14) in 1919 using a 1.5% to 2.0% sodium hydroxide solution to increase the nutrient value of straw. This procedure is limited because of the large volume of dilute sodium hydroxide required, the tedious washing procedure, and the loss of soluble nutrients. Wilson and Pigden (98) developed the dry process of alkali treatment using 100 g of straw or wood to 6.9 g of sodium hydroxide dissolved in 30 mls of water.

Gharib et al. (40) evaluated the variables of time, temperature and concentration of sodium hydroxide for maximum treatment affects and found the digestibilities of poplar bark to be maximized when the treatment lasted 1 day instead of 20 days and 9 - 20 g sodium hydroxide per 100 g of bark. Digestibility was not greatly influenced by varying temperatures.

Ferguson (37) treated wheat straw with a 1.5% sodium hydroxide solution for 22 hours at 10 to 15 C using ten times the straw weight solution. The straw lost 20% of its dry matter, but digestibility by sheep was increased from 30% to 70% with 90% of the cellulose being digested. Jones and Klopfenstein (55) increased the DM digestibility of poor quality roughages and reduced the cell wall constituents by treating with 4% sodium hydroxide.

Kaufman et al. (61) evaluated the digestibility of wood and straw when treated at high temperatures with saturated steam and washed with dilute alkali. In vitro digestibilities obtained after this treatment were: wood 37%, wheat straw 80%, and oat hulls 90%.

Zafren (100) treated straw with ammonium hydroxide instead of sodium hydroxide. When fed to young bulls, treated straw was more than twice as digestible as the untreated straw.

It is hypothesized that the alkali saponifies the ester linkages of the lignin-cellulose complex thereby permitting additional swelling of the wood increasing the decomposition of the cellulose (36, 41). Alkali combines with acetyl groups and forms acetates. If ammonium hydroxide is used instead of sodium hydroxide, the ammonium acetate formed a source of available nitrogen for rumen microorganisms (100).

Feist et al. (36) treated various hardwoods with a .5 to 1% sodium hydroxide solution. In vitro dry matter digestibility of aspen increased from 35 to 50% and IVDMD for the other woods increased from 5 to 56%. Millett et al. (72) increased IVDMD of hardwood to equal that of medium quality hay by treating with 10% sodium hydroxide. When aspen was treated with anhydrous liquid ammonia IVDMD was 50%. Huffman (52) increased IVDMD of poplar and alder after treatments of 2 to 4% sodium hydroxide solution for 1.5 hours.

Mellenberger et al. (70) fed untreated and alkali treated aspen to goats in high roughage or high concentrate rations. The DM digestibility of alkali treated aspen was 48% and 31% for untreated aspen in a high concentrate ration. Digestibilities were 52% and 41%, respectively, in high roughage rations.

Keith and Daniels (63) fed alkali treated hardwood sawdust to cattle. They found that the acid detergent fiber, cellulose, ash and IVDMD were increased while the lignin content was decreased when 1.0% alkali treatments were used. Optimum IVDMD was obtained when the sawdust was treated with 2.0% alkali. When Keith and Daniels (62) fed a ration containing 25% of 1% sodium hydroxide treated hardwood sawdust Holstein steer calves, no digestive problems were encountered.

(b) Acid treatment

Keith and Daniels (63) treated hardwood sawdust with 1.0 to 25% sulfuric acid for 24 hours. Acid detergent fiber, and lignin were decreased with the sulfuric acid treatments. The highest IVDMD was with sawdust treated with 2.5% sulfuric acid although it was not significantly more digestible than either 1.0% sulfuric acid or 1.0% sodium hydroxide treated sawdust. Utilization of hardwood sawdust by Holstein steer calves was not improved by acid treatment (62).

Butterbaugh and Johnson (20) compared the use of low acid and high acid treatments on wood residue fed to growing lambs. They found that there were no significant differences in weight gains of lambs fed 25 to 50% low acid treated wood residue rations. Weight gains and DM digestibilities decreased when fed 20 to 25% of high acid treated residue. The cellulose content of wood treated with acid was reduced from 57% to 48% with low acid treatment and to 11% with high acid treatment.

Hajny et al. (46) compared IVDMD of various woods before and after treatments with mild sulfuric acid. Before the acid treatment, digestibilities were: sweatgum - 15.9%, aspen - 13.8%, west larch heart - 6.4%, west larch sapwood - 3.1%, yellow birch - 19.4%, and hard maple - 8.3%. When treated with mild acid, the digestibilities were: sweatgum - 25.6%, west larch heart - 21.6%, west larch sapwood - 22.7%, yellow birch - 22.5% and hard maple - 21.0%.

Klopfenstein et al. (65) subjected various roughages to a pressure of 28 kg/cm^2 in the presence of water, .5% hydrochloric acid or 4% hydrogen peroxide and studied the effects on IVDMD. They found that these treatments increased IVDMD of all roughages treated.

(c) Chlorine dioxide treatment

Sullivan (92) evaluated the effect of chlorine dioxide on the lignin content and cellulose digestibility of forages. Chloride dioxide treatment resulted in a marked decrease in the acid-insoluble lignin content and a significant increase in the IVDMD of the cellulose.

3. The nutritive value of other wood products.

(a) Pulp residues

Fritschel et al. (39) evaluated aspen bark and pulp residues for ruminant feedstuffs. The fines used were a by-product of an ammonia-based sulfite tissue mill. When ewes and lambs were fed rations containing either alfalfa hay, 72.5% pulp fines, or 72.5% aspen bark, performances were similar and satisfactory. When steers were fed either rations containing alfalfa haylage or 75% pulp fines, average daily gain (kg/day), dry matter intake (kg/day) and feed efficiency (kg feed DM/kg gain) during the 101-day trial were 1.09, 8.50 and 7.8 for the alfalfa haylage group, respectively, and .45, 7.68, 17.1 for the pulp fine group, respectively. When beef cows were fed a mix containing 83% pulp fines in a 7-month field trial, the cows consumed the pulp fines readily, and performance was equal to that expected from cows fed conventional rations.

Pelleted feedlot starter rations containing either oat hulls or pulp fines were compared with corn silage as aids in switching cattle to high-grain finishing rations. Measurements of body weight changes were highly variable, but daily gain averaged 1.38, .76, .74 and .63 kg/day for the corn silage, oat hulls, and two pulp fines treatment groups, respectively.

Saarinen et al. (82) evaluated ten different pulps and 10 different methods of pulping using principally birch wood and some spruce. Digestibilities obtained with sheep varied from 27.5 to 89.9%. Pulps prepared by means of alkali methods of pulping were somewhat more digestible than corresponding pulps treated with acids or chlorite. Baker et al. (7) evaluated ten chemical pulps and two mechanical pulps. In vitro dry matter digestibilities ranged from 67 to 98% for chemical pulps and fines, and 0 to 7% for mechanical pulp and fines.

Tarkow and Feist (93) stated that the chemical changes of wood after mild pulping are caused by increased plasticization (fiber saturation point). Conventional pulping procedures raise the fiber saturation point of all species of wood. While the fiber saturation point is doubled for hardwood, softwoods are essentially unaffected.

(b) Waste paper

Mertens et al. (71) studied the in vitro digestion of selected waste papers. They found that the IVDMD for brown wrapping paper, brown cardboard, glossy magazine paper, and other waste papers were 83.6%, 71.8%, 38.4 to 46.8%, and 20 to 25%, respectively.

Hawkins et al. (49) compared the microbial activity of ruminants fed a paper ration and a conventional ration (47% concentrate:53% roughage). The paper replaced 33.8 to 50% of the ration DM for 2 weeks or more and to one cow continuously. The initial ration consisted of 50% paper blended with molasses, SBM, urea, minerals, and vitamins. Digestibility of dry matter was 60.2% and the total VFA in rumen fluid of cows fed the paper ration compared favorably with the VFA in cows receiving a conventional ration.

Hansen et al. (47) evaluated paper and feedlot solid waste as compared to alfalfa and an all concentrate control. Feed efficiencies suggested that the paper, primarily cellulose, is readily digestible when fed to beef cattle. There were no significant differences observed for fat thickness, marbling score or carcass grade.

Millett et al. (73) evaluated pulp and paper making residues as feedstuffs for ruminants. In vivo digestibilities were aspen (screen rejects from sulfate pulping) - 58%; unbleached fines from a pine Kraft Mill - 48%; unbleached parenchyina cell fines from aspen sulfite - 52%; and bleached fines from a mixed hardwood Kraft Mill - 78%.

(c) Wood molasses

Colovos et al. (23); Burkitt et al. (19); Jones (54); and Doxin et al. (31) found that wood molasses offers a nutritive value similar to that of cane molasses.

D. Nutritional value of wood in lactating dairy cow rations.

In 1925, Archibald (4) fed 20% hydrolyzed sawdust of douglas fir and eastern white pine to lactating dairy cows for eleven weeks. The ration also contained mixed hay and a grain mix. Cows fed douglas fir produced 44.8 kg less milk and cows fed white pine produced 19.9 kg less milk than the cows fed the control ration during the eleven week period. Pine was 46% digestible while douglas fir was 33% digestible.

Keyes (64) evaluated wood molasses as a feed for milking cows and found its value to be the same as cane molasses.

Satter et al. (84) evaluated aspen sawdust as a roughage replacement in high concentrate dairy rations. In experiment 1, twenty lactating Holstein cows were placed into four groups. Group 1 was fed grain mix with 10% aspen sawdust, group 2 was fed grain mix with 10% aspen sawdust and 5% sodium bentonite, group 3 was fed grain mix and 20% aspen sawdust, and group 4 was fed a grain mix and 30% aspen sawdust. Milk production, percent protein, percent solids not fat, percent feed intake and body weights were similar with all four rations. In experiment 2, twelve cows were put into three groups and were fed either a grain mix plus 2.3 kg alfalfa hay; a grain mix plus 12% aspen sawdust and 2.3 kg alfalfa hay; or a grain mix plus 12% aspen sawdust, 5% sodium bentonite, 5% sodium bicarbonate and 2.3 kg hay. There were no significant effects in milk production, composition, feed intake of body weights.

Satter et al. (83, 84) divided twelve lactating cows into three groups of four and fed either equal parts of hay and pelleted concentrate; limited hay and pelleted concentrate containing 32% aspen sawdust; or limited hay and pelleted concentrate. There were no significant ration effects on milk production or percent milk protein. Fat percent increased when cows were fed the ration containing 32% aspen sawdust, and the acetate:propionate ratio also increased.

When lactating dairy cows were fed 10 to 20% of dry matter as aspen chips, they ate more and produced more milk than cows fed only corn silage (2). Processed aspen chips were fed at levels of 0, 10, and 20% along with corn silage. The rations were fed to five lactating cows each for six weeks. Cows fed aspen ate 1.5 kg (DM) more per day than those fed silage alone. This increase was offset by a decrease in the digestibility of the total ration. Milk yield increased by 1.25 and 1.07 kg/day for the 10 and 20% aspen rations, respectively.

Adams and Thomas (1) fed wood fines obtained from ammonium sulfite treated pulpwood. There were no differences in milk fat when 3.4 kg of corn silage were replaced by equal amounts of wood fines in a balanced ration. No adverse effects on health were observed in cows fed wood fines for a period of over two years. When cows were suddenly introduced to the fines their milk production fell slightly over a short period of time and then adjusted to normal production. Numerous dairymen in Northeastern PA fed these fines to their cows successfully during the forage shortage in 1978.

MATERIALS AND METHODS

Procurement of Aspen Material

The entire aspen tree, including all branches, leaves and bark, was harvested in the early Fall in Brainerd, Minnesota, and chipped in Burnsville, Minnesota, by the Total Tree, Inc. The aspen chips were shipped by truckload to De Smet, South Dakota, where they were dried, pelleted and bagged by the Peavey Feed Plant.

Experimental Rations

Two rations were formulated to evaluate aspen pellets as a partial roughage source for lactating dairy cows. Ration A contained 30% of the dry matter (DM) from aspen pellets, 30% DM from corn silage, and 40% DM from a 28% crude protein concentrate mix (Table 1). Ration B contained 60% DM from corn silage and 40% DM from the concentrate mix. Because aspen contains relatively low amounts of protein, the concentrate mix was formulated to be high in protein to assure meeting the nutritional requirements of all cows (74).

Experimental Design

Ten Holstein cows were paired on the basis of milk production and stage of lactation and one cow from each pair randomly assigned to groups 1 or 2. All cows were at least 80 days into lactation at the start of the trial. The two treatment rations A and B were evaluated using a complete switchback design trial with three periods of five weeks each. Cows were adjusted to the rations the first two weeks of each period and data were collected during the last three weeks of each period. Group 1

TABLE 1. Ration ingredient composition.

Item	Ration: Aspen	Ration: Control
	------- % of dry matter ------	
Aspen wood pellets	30	--
Corn silage	30	60
Concentrate mix[a]:		
Corn, ground shelled	20	20
Soybean meal	18.4	18.4
Dicalcium phosphate	.6	.6
Limestone	.5	.5
Trace mineralized salt	.5	.5

[a]Plus 8,800 IU supplemental vitamin A/kg and 2,200 IU supplemental vitamin D/kg.

was fed ration A during periods 1 and 2, and ration B during period 2, whereas group 2 was fed ration B during periods 1 and 3, and ration A during period 2. The cows were housed and fed individually in stanchions and milked in a double-five Herringbone parlor.

Sample Collection

Milk production was recorded daily and AM-PM sample collections were made during the third, fourth, and fifth weeks of each period for analyses. Cows were weighed before and after each period. All feed components, including aspen pellets, corn silage and concentrate mix were sampled weekly. The weekly samples were composited each period for analyses. Daily feed intakes and feed refusals were recorded for each cow. During the fourth week of each period feed refused (weighback), and a representative feces sample was collected from each cow for analyses. Also during the fourth week of each period, samples of rumen contents were collected from each cow via stomach tube into 100 ml bottles containing .5 ml saturated mercuric chloride three hours after feeding.

Chemical Analysis

Milk samples (AM-PM composites) were analyzed for protein by Pro-milk[1], Mojonnier total solids (5), and milk fat using the Milko-tester, MK-II[1]. Milk flavor was evaluated by a group of four experienced judges of dairy products using the official ADSA-DFISA score card. Milk samples were composited by group each period for analysis of fatty acids.

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[1]N. Foss Electric, Hillerod, Denmark.

Fat was extracted from the composited milk samples using the Mojonnier method (5). Butyl esters were prepared by adding 3 ml of Boron trifluoride in butanol[2] to a .25 ml sample of milk fat. The contents were then refluxed in a 100 ml pear shaped flask for 10 minutes. Following cooling, the excess butanol was removed by the washing procedure of Jones and Davison (53). Samples were then analyzed for fatty acids (FA) by gas liquid chromatography using a 2.4 M x 0.32 cm stainless steel. column, containing 100-120 gas chrom P coated with 10% EGSS-X, organo-silicon polymer[3]. Each run was temperature programmed from 70 C to 200 C at 6^{o}/minute (28).

Feed, weighback and feces samples were dried in a forced air oven at 60^{o} C to determine dry matter. Dried samples were ground to pass through 20-30 mesh (1-mm) screen using a Wiley mill. Wet silage and feces samples were analyzed for total nitrogen via Kjeldahl (5). Dried feed, weighback, and feces samples were analyzed for crude protein (CP), ash and ether extract using A.O.A.C. methods (5); and neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) as described by Goering and Van Soest (43). Samples of rumen contents were immediately analyzed for pH. A 10 ml aliquot of rumen fluid was centrifuged, frozen, and later analyzed for ammonical nitrogen as described by Chaney and Marbach (21). Another 10 ml aliquot of rumen fluid was acidified with 2 ml of 25% metaphosphoric acid, centrifuged, and the supernatant frozen until later analyzed for volatile fatty acids (VFA) by gas liquid chromatography using a neopentylglycol succinate

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[2]Supelco, Inc. Bellefonte, PA.

[3]Applied Science Laboratories, State College, PA.

column as described by Baumgardt (10) and Erwin (35).

Statistical Analysis

Statistical analyses were performed using the analysis of variance applied to switchback trials involving three test periods as described by Brandt (17).

RESULTS AND DISCUSSION

Milk production, composition, including fat, total solids and protein; and milk flavor were similar from cows fed either aspen or control rations (Table 2). In a previous trial (2) when cows were fed aspen chips that replaced 10 and 20% of the corn silage, milk yield was increased and milk protein decreased slightly while there was no change in milk fat. When aspen sawdust was partially substituted in a high concentrate dairy ration (83, 84), milk yield and milk protein were not affected; however, milk fat increased.

The fatty acid composition of the milk fat was similar for both rations with the exception of 18:0 and 18:1. The 18:0 ($P<.05$) and 18:1 ($P<.01$) fatty acids were higher in the milk fat of cows fed the aspen ration. Kamstra (unpublished data) evaluated the composition of aspen obtained from eight months of sample collected from various locations in South Dakota and Minnesota, and found that the lipid fraction contained mostly long chain fatty acids (15:0 to 28:0). Long chain fatty acids in milk are influenced by diet as in the mammary gland these fatty acids are absorbed from the blood after some hydrogenation in the rumen (77, 78).

Average composition of the aspen pellets, corn silage and concentrate mix are presented in Table 3. Aspen pellets contained less protein and ash than corn silage, but more neutral detergent fiber, acid detergent fiber, cellulose, and acid detergent lignin. The composition of the aspen pellets was similar to material used by others (34, 44).

Crude protein, ether extract and ash were slightly lower in the total aspen ration as compared to the control ration (Table 4). Protein

TABLE 2. Milk production, composition and flavor from cows fed aspen and control rations.

Item	Ration: Aspen	Ration: Control	SE[c]
Production, kg/day	20.94	21.35	.38
Fat, %	3.49	3.50	.16
Total solids, %	12.26	12.22	.14
Protein, %	3.09	3.08	.05
Flavor score[a]	8.77	8.77	.10
Fatty acids	----------------	(wt %)	-------------
4:0	1.44	1.70	.55
6:0	2.63	2.83	.15
8:0	1.78	1.95	.20
10:0	4.06	4.28	.26
12:0	4.82	5.33	.57
14:0	13.66	14.99	.89
16:0	32.68	33.84	1.93
16:1	2.54	2.53	1.37
18:0	13.23*[b]	11.16	1.05
18:1	22.43**	20.27	.43
18:2	1.14	1.17	.40

[a]Score based on a scale of 1 to 10 with 10 being the best score.

[b]Different from control, *$P<.05$, **$P<.01$.

[c]Standard error.

TABLE 3. Average composition of aspen wood pellets, corn silage and concentrate mix.

Item	Feedstuff		
	Aspen	Corn silage	Concentrate mix
	----------	%	----------
Dry matter	96.9	42.0	95.5
	----------	(% of DM)	----------
Crude protein	1.9	9.8	28.0
Ether extract	2.1	2.6	2.4
Ash	2.2	5.6	7.5
Neutral detergent fiber	80.3	48.5	14.4
Acid detergent fiber	64.5	27.1	6.5
Cellulose	46.5	19.8	3.8
Acid detergent lignin	16.9	5.3	2.8

TABLE 4. Average composition of rations fed.

Item	Ration: Aspen	Ration: Control
	%	%
Dry matter	79.9	63.4
	(% of DM)	(% of DM)
Crude protein	14.6	16.5
Ether extract	2.4	2.6
Ash	5.5	6.4
Neutral detergent fiber	44.2	35.9
Acid detergent fiber	29.6	19.5
Cellulose	21.1	13.9
Acid detergent lignin	7.6	4.4

was higher in the control ration because the concentrate mix was formulated so that the aspen ration would not be deficient in protein. Dry matter, neutral detergent fiber, acid detergent fiber, cellulose, and acid detergent lignin were higher in the aspen ration as compared to the control ration. Conrad et al. (24) stated that intake of low digestibility diets was a function of body weight, rate of passage and digestibility. The fiber level of the aspen ration may be high enough to limit feed intake due to gut fill during peak of lactation. For this reason including aspen as more than 30 percent of the total dry matter ration would not be recommended.

There was no difference in daily DM intakes between cows fed aspen or control rations (Table 5). This agreed with results found in other studies (83, 84), whereas in a previous study (2) cows consumed more dry matter when fed aspen. Cows fed both the aspen and control rations consumed 3.2 percent of their body weight as feed dry matter which were within expected ranges (74).

Cows were fed daily rations of about 10 percent over that what they could consume so that the weighback could be evaluated to determine if the aspen was rejected. Composition of feeds refused and the composition of the ration consumed are presented in Tables 6 and 7, respectively. Measurements of the composition of feeds refused were used to calculate the ration consumed. This was derived from the difference between the ration fed (Table 4) and the composition of the feed refused. The refusals contained slightly less protein and more fiber, but these differences were essentially the same for both aspen and corn silage groups indicating no difference between rations in the animals selecting

TABLE 5. Average daily dry matter intake of cows fed aspen and control rations.

Item	Ration: Aspen	Ration: Control	SE[a]
	------- (kg/day) --------		
Total ration fed	21.80	21.12	--
Weighback	2.44	1.84	.68
Ration consumed	19.36	19.28	.68

[a]Standard error.

TABLE 6. Composition of feed refusals.

Item	Ration Aspen	Ration Control	SE[b]
	------- % ---------		
Dry matter	69.00**	52.85	5.83
	----(% of DM) -----		
Crude protein	10.02	11.54	1.57
Ether extract	1.83*	1.87	.20
Ash	4.00**	5.57	.36
Neutral detergent fiber	56.70**	45.69	2.86
Acid detergent fiber	39.44**	25.81	2.16
Cellulose	30.20**	19.55	1.84
Acid detergent lignin	8.66**	4.58	1.16

[a]Different from control, *P<.05, **P<.01.

[b]Standard error.

TABLE 7. Average composition of ration consumed.

Item	Ration Aspen	Ration Control
	%	%
Dry matter	87.90	67.90
	(% of DM)	(% of DM)
Crude protein	15.24	17.01
Ether extract	2.46	2.65
Ash	5.68	6.43
Neutral detergent fiber	42.61	34.85
Acid detergent fiber	28.41	18.93
Cellulose	19.94	13.33
Acid detergent lignin	7.44	4.36

certain feed components.

Body weights of cows were similar for cows fed aspen (595.8 kg) and control (596.6 kg) rations. This agreed with the results of previous work (83, 84).

Volatile fatty acids (VFA), pH and ammonia in the rumen contents of cows fed aspen and control rations are presented in Table 8. Ruminal pH was higher ($P<.01$) in cows fed the aspen ration three hours after feeding, while the total VFA were lower ($P<.01$). This agreed with previous studies (83, 84) that showed a decrease in the total VFA in the rumen samples of cows fed aspen sawdust. This suggests that at the time of sampling less fermentation of products occurred in the rumen of cows fed the aspen ration.

Concentrations of the major VFA acetate, propionate and butyrate were also lower with the aspen ration, possibly confirming a slower rate of fermentation. However, when expressed as percentage of the total moles of VFA (mole percent), there were no significant differences in the proportions of the various VFA, with the exception of a slightly higher mole percentage of isobutyrate and isovalerate ($P<.05$) in rumen samples from cows fed aspen. This suggested that the rations were fermented in essentially the same manner, but at a slower fermentation rate when fed aspen.

Rumen ammonia concentrations were similar for cows fed aspen and control rations. The rumen ammonia concentrations fell within an expected range (81, 99) for both rations, although a higher ammonia concentration might be expected in the rumen of cows fed the control ration because of a higher protein percent as compared to the aspen ration.

TABLE 8. Volatile fatty acids, pH and ammonia in rumen contents of cows fed aspen and control rations.

Item	Ration: Aspen	Ration: Control	SE[b]
	--- (Micromoles/ml) -----		
Volatile fatty acids			
C_2	24.65**[a]	31.94	2.66
C_3	12.44**	14.18	1.61
Ci_4	.77	.75	.14
C_4	9.47**	13.44	1.76
Ci_5	1.31	1.40	.20
C_5	.90*	1.04	.13
Total	48.71**	63.17	5.65
	------ (mole %) ---------		
C_2	50.92	51.27	2.10
C_3	23.70	22.42	1.31
Ci_4	1.53*	1.18	.18
C_4	19.36	21.22	1.94
Ci_5	2.64*	2.27	.16
C_5	1.84	1.64	.14
C_2/C_3	2.17	2.29	.17
pH	6.77**	6.54	.07
Ammonia, mg/100 ml	6.19	6.10	.85

[a]Different from control, *P<.05, **P<.01.

[b]Standard error.

Composition of feces from cows fed aspen and control rations (Table 9) indicated trends expected on the basis of the composition of rations fed. That is, protein, ether extract and ash were lower; and the fiber fractions were higher in feces from cows fed aspen.

TABLE 9. Composition of feces from cows fed aspen and control rations.

Item	Ration		
	Aspen	Control	SE[b]
	%		
Dry matter	20.58	17.85	3.20
	(% of DM)		
Crude protein	10.85**[a]	15.35	1.06
Ether extract	1.74**	1.90	.15
Ash	7.56*	10.38	.68
Neutral detergent fiber	62.21**	47.94	2.66
Acid detergent fiber	44.48**	29.71	1.51
Cellulose	31.30**	20.00	1.11
Acid detergent lignin	10.69**	6.24	.94

[a]Different from control, *P<.05, **P<.01.

[b]Standard error

SUMMARY

When replacing 50% of the roughage with aspen pellets in a ration for lactating dairy cows, there was no effect on milk production, composition, and flavor. However, the ration was supplemented with a high protein concentrate mix which may not be an economical advantage. The total aspen ration supplied the cows with more than enough energy, therefore a critical evaluation of the extent aspen was utilized was not possible.

Aspen may be potentially useful as a feed for lactating dairy cows when there is a critical feed shortage and if aspen is readily available at a competitive price. Levels above 30% of the total ration DM may decrease milk production especially if fed at the peak of production as gut fill may be a limiting factor.

Rations containing aspen must be supplemented with a high protein source as well as calcium, phosphorus, and vitamin A. If fed to non-producing cows, less supplementation would be needed. Therefore aspen has greatest potential as a feed source for dry cows, yearlings, and cows in mid to late lactation.

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squares analysis of variance was used to analyze the data. It was determined there were no significant differences in yields of cheddar cheese when using Superstart concentrated starters and conventional bulk starter.

The efficiency of conversion of milk to cheese curd can be evaluated using accepted formulas used to predict yields. Surveys of cheese yield and the casein and fat contents of milk were used to develop the following formula for predicting yield of cheddar cheese (49).

$$\text{lb cheese/100 lb milk} = \frac{(0.93F + C - 0.1)\ 1.09}{1.00 - W}$$

In which:

F = % milk fat = 3.35%.

C = % milk casein = 2.27%

W = lb water in 1 lb cheese = .37 lb.

Substituting the values determined in this study, predicted yields should approximate 9.18%. Overall yields for all cheeses was 9.43% which indicates excellent solids retention and curd strength during cheesemaking.

Organoleptic Evaluation

A panel of three to four experienced judges evaluated the cheeses over a 9 mo period. Flavor and body and texture of the cheese was evaluated at 1 mo of age and continued through the 9 mo. A ten point hedonic scale was used for flavor and a five point scale for body and texture. Tables 16 and 17 summarize the results of organoleptic evaluation. The panel determined there was no detectable difference in cheese made from Superstart or Bulk Set cultures. Average flavor and body and texture scores for both treatments was 8.9 and 4.2, respectively. The age of the cheese judged had a highly significant effect ($P<.01$) on flavor scores. The cheese appeared to exhibit the most desirable flavor at 4 mo of age. Age of cheese had no effect on scores of body and texture. A summary of statistical analysis for flavor and body and texture is shown in Table 18.

TABLE 16. Flavor score of manufactured cheddar cheeses[a,b].

	Month									
	1	2	3	4	5	6	7	8	9	Mean $\overline{X}$
Superstart	9.2	9.0	9.4	9.2	8.9	8.6	8.5	8.6	9.1	8.9
Bulk Set	9.2	9.0	9.0	9.2	8.8	8.7	8.7	8.7	9.0	8.9

[a]Based on a hedonic scale with 10 as perfect score.

[b]Monthly values are means of eight replications.

TABLE 17. Body and texture score of manufactured cheddar cheeses[a,b].

	Month									
	1	2	3	4	5	6	7	8	9	Mean $\overline{X}$
Superstart	4.2	4.1	4.3	4.1	4.2	4.3	4.3	4.3	4.3	4.2
Bulk Set	4.1	4.2	4.1	4.3	4.4	4.3	4.2	4.2	4.3	4.2

[a]Based on a hedonic scale with 5 as perfect score.

[b]Monthly values are means of eight replications.

TABLE 18. Statistical analysis of treatment effects on cheddar cheese flavor and body and texture.

Factor	Flavor[a]	Body and Texture[b]
Starter culture	N.S.	N.S.
Age of cheese	**	N.S. (P = .06)
Starter X age interaction	N.S.	N.S.

[a]Based on a hedonic scale with 10 as a perfect score.

[b]Based on a hedonic scale with 5 as a perfect score.

* Significant (P<.05).

**Highly significant (P<.01).

N.S. = Not significant.

SUMMARY

The objectives of this research were to compare cheddar cheese yields when using conventional bulk starter and Superstart concentrated starters. Another objective was to evaluate composition and organoleptic characteristics of cheese made from both culture types.

Fresh whole milk was used to manufacture cheddar cheese two consecutive days of each week for a total of sixteen vats with eight replications with each culture. All cheeses were cured at 5 C for 9 months. Sampling, analyses, and organoleptic evaluations were done on fresh cheese and at monthly intervals.

Weights were accurately taken to ascertain crude yield information. Composition analyses performed on the milks, cheese, and wheys included: total solids, fat, total nitrogen, ash, phosphorus, calcium, magnesium, potassium, and sodium. Nitrogen fractions in the milks were determined by measuring levels of non-casein and non-protein nitrogen. Solids-not-fat, casein protein, and lactose were derived by difference. Cheese was also analyzed for pH, soluble nitrogen, and lactic acid. Flavor and body and texture of the cheese were evaluated by a panel of judges on a monthly basis for 9 mo. Yields of cheddar cheese were expressed as percent cheese (adjusted to 63% solids in the cheese) recovered from total milk weight.

Using least squares analysis of variance to test the data, no significant differences ($P<.05$) existed between cheddar cheese yields when conventional bulk starter or Superstart concentrated cultures were used. Result of organoleptic evaluation indicated there were no detectable differences in flavor and body and texture of cheeses

made with either of the two starter culture types. Compositional characteristics of cheeses made using the respective starter cultures were almost identical; but significant differences were seen in the chemical changes occurring during curing.

Although yield and cheese composition and quality were not improved when using Superstart concentrated cultures, this culture type does offer other advantages (44, 57):

1) Convenience - No starter preparation is necessary prior to the manufacture of cheese.
2) Culture reliability - Cultures are pretested for activity.
3) Improved daily performance - Cultures result in more uniform acid development from day to day.
4) Improved strain balance - The strain balance in the culture remains constant. Strain balance can change when the culture is transferred in milk.
5) Greater flexibility - The cheesemaker is able to use several different strains of cultures on the same day for producing different styles and types of cheese.

Once a skilled art, cheesemaking now depends more and more on scientific technology. Any company manufacturing cultured products must exercise not only sound management practices as they relate to marketing, sales, and product development; but also utilize and maximize all the best known technologies in manufacturing practices and equipment designs. Much of the United States' output of cheese depends on mechanized methods developed through cooperation between industry and research universities. It is important therefore, to review, periodically, technology and procedures as they relate to equipment changes and innovative processing techniques.

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